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Anatomical factors predicting lower calyceal stone clearance after extracorporeal shockwave lithotripsy

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Abstract
Objective: To determine the role of the lower pole infundibular parameters as predictors of stone clearance following extracorporeal shock wave lithotripsy (ESWL).
Subjects and methods: Between March 2001 and February 2004, 243 renal units in 239 patients with isolated lower calyceal stones were treated by ESWL. Stone-free status was assessed after 3 months by plain X-ray abdomen and a kidney ultrasound scan. Persistent stone fragments ≥6 months after the completion of treatment was defined as residual stone. Radiogaphic parameters were obtained from intravenous urography (IVU). SPSS version 15.0 was utilized for all statistical analysis.
Results: The median age of all patients was 38 years (range: 20–70 years). The male to female ratio was 2.1:1. The mean stone size was 1.3 ± 0.7 cm. Overall, 144 renal units (60.9%) had undergone one or two sessions of ESWL, 43 (17.7%) 3, while 46 (18.9%) ≥4 sessions, with mean of 2.1 sessions.
Stone-free rates differed significantly between favorable and unfavorable infundibular length (IL), and infundibular width (IW) (p value = 0.01, p = 0.0001, respectively). Infundibulopelvic (IP) angle had no statistically significant effect on stone-free rate (p = 0.1).
The effect of stone size on stone-free rate in two groups revealed better overall results in favorable anatomy group than in unfavorable group in stone sizes, 0.5–1.0 cm, 1.1–1.5 cm, 1.6–2 cm and 2.1–2.5 cm (76.7%, 87.5%, 100%, and 56.2% vs. 41.1%, 55.5%, 66.6%, and 50%; p = 0.04, 0.10, 0.10, 0.80, respectively).
Conclusions: This study shows that lower infundibular length and width are significant anatomical factors in determining stone clearance following ESWL treatment of lower calyceal stones and these should be assessed before planning the treatment for lower calyceal stones.

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Introduction

Stone disease is endemic in Pakistan and constitutes 60% of the urological workload [1,2]. Extracorporeal shock wave lithotripsy (ESWL) is the treatment of choice for majority of urinary calculi, especially those smaller than 2 cm in size [3,4]. However, the efficacy of ESWL as a primary treatment for lower pole stones remains controversial. The problem in lower pole stones is fragment retention rather than stone disintegration. One important factor that predicts the success of ESWL in lower pole stones is the calyceal anatomy [5–10]. The lower pole infundibular (IF) length, infundibular width (IW) and the infundibulopelvic (IP) angle on intravenous urography (IVU) have been shown to impact stone clearance [6,8,10–13]. Among these radiological parameters, the definition of IP angle has varied among the studies and remains problematic and controversial [14]. Measurement of the angle by Elbahnasy depended on fixed points and hence provided more consistent landmarks [6]. He used ureteropelvic axis rather than pelvic axis and vertical axis of the lower infundibulum. The use of ureteropelvic axis rather than pelvic axis resulted in a more acute angle, thus a lower cut off point was advisable. Different investigators used different cut-off values of the IP angle resulting in conflicting results [4,8–14]. However, the mean angle in many studies was around 40–50 degrees rather than 90 degrees found in the original resin endocast study of 146 cadaveric kidneys [4,5]. Therefore, we set a cut-off point at 45 degrees to see if this cut-off value is useful.

In this study, we aimed to evaluate the role of radiographic spatial anatomy using the above infundibular parameters as predictors of stone clearance following ESWL.

Subjects and methods

The study was carried out at adult urology department of Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan. Between March 2001 and February 2004, 243 renal units in 239 adult patients (>20 years) of either gender with isolated lower calyceal stones were treated by ESWL. Electromagnetic lithotripter Doli (Doli 50 (1995 Make), Dornier, Germany) was used to treat stones. Therapy was usually started at power 20 and increased up to power 60 and number of shock waves per session was 3000. The interval between the sessions was a minimum of one week. Stone free status was assessed 3 months after the last shock wave lithotripsy session by plane X-ray abdomen and renal ultrasound. Stone fragments less than 4 mm in size were subjected to inversion therapy and mechanical percussion. Any evidence of persistent stone fragment 6 months after the completion of treatment was defined as residual stone.

Written informed consent was obtained from all study participants and the ethical review committee of the institute approved the study.

We grouped the radiological anatomy parameters of the lower pole into favorable and unfavorable categories to determine the effect of this grouping on the stone clearance rate. Favorable anatomy group comprised of IL of ≤30 mm, IW of ≥5 mm, and IP angle of ≥45°. Unfavorable group had just the opposite values.

Data analysis

The software program statistical package for social sciences (SPSS) for Windows version 15.0 (SPSS Inc., Chicago, IL, USA) was utilized for all statistical analysis. Mean ± standard deviation (SD) and median (range) were computed for continuous variables like age and duration of disease. Numbers and percentages were used to summarize the categorical variables like gender distribution, stone clearance rate and failure rate. The chi-square test was applied to see the association of lower pole anatomical factors with stone-free rate. $P < 0.05$ was considered as significant.

Table 1 The main demographic and stone-related characteristics.

Total number of patients	239
Males, n [%]	164 (68.6)
Females, *n* [%]	75 (31.3)
Male to female ratio	2.1:1
Median age [in years]	38
Age range [in years]	20–70
Mean stone size [in cm]	1.3 ± 0.7 cm
Stone size, range [in cm]	0.5–2.5

Results

A total of 239 patients and 243 renal units were treated for inferior calyceal calculi with ESWL. The median age of all patients was 38 years (range: 20–70 years). The peak age group in this series was 20–40 years comprising 73.4% of all patients. The male to female ratio was 2.1:1.

The mean stone size was 1.3 ± 0.7 cm. The majority of renal units (167, 68.7%) had stone size between 0.5 cm and 1.5 cm. Twenty-eight renal units (11.5%) had stones of 1.6 to 2.0 cm and 48 units (19.75%), 2.1 to 2.5 cm in size. The main demographic and stone related parameters are given in Table 1.

One hundred forty four renal units (60.9%) had undergone one or two sessions of ESWL, 43 (17.7%) three, while 46 (18.9%) had four and five sessions (Fig. 1), with a mean of 2.1 sessions.

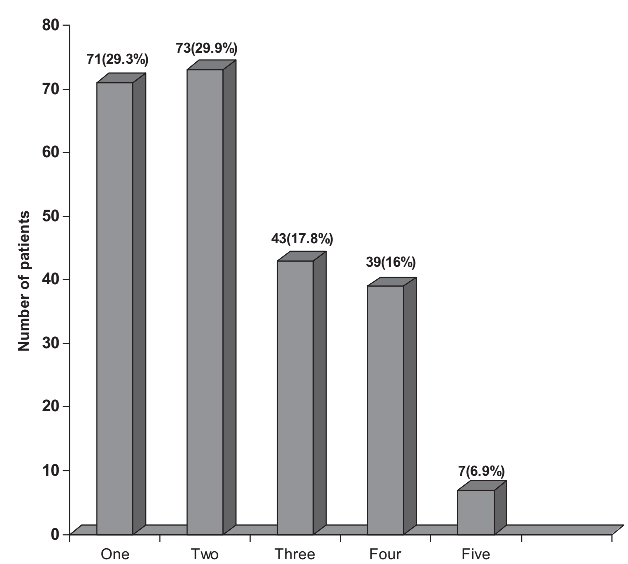

Figure 1 Frequency of treatment sessions of ESWL for lower calyceal stones in 239 patients.

Table 2 Stone-free rates according to lower pole anatomical parameters.

Variables	Total number	Stone-free rate, *n* [%]	*p* value
Infundibular length [mm]			
≤30	145 (59.7%)	116 (79.8%)	0.01
>30	98 (40.2%)	42 (42.8%)	
Infundibular width [mm]			
≥5	159 (65.5%)	132 (83.3%)	0.0001
<5	84 (34.5%)	39 (46.7%)	
Infundibulopelvic angle			
≥45°	85 (35%)	56 (65.6%)	0.1
<45°	158 (65%)	76 (48.3%)	

Sixty-two (25.9%) patients had different complications. Pain was the commonest complication occurring in 38 (16.1%) and steinstrasse in 19 (8%) and obstruction in 5 (2.2%) patients.

The effect of lower pole anatomy on stone free rate showed better results in favorable anatomy group. IL of 30 mm or less had positive impact on stone free rate as compared to greater IL, 79.8% vs. 42.8% (p value = 0.01) which was statistically significant. Similarly, IW had definite impact on stone free rate. IW of ≥5 mm had beneficial effect on success rate, 132 (83.3%) patients achieved stone free status while 39 (46.6%) patients with IW ≤5 mm achieved stone free status (p = 0.0001). On the other hand, IP angle had no statistically significant effect on stone free rate. Angle of ≥45° and <45° had no significant difference in stone free rate, 56.6% vs. 48.3% (p = 0.1), as shown in Table 2.

The effect of stone size on stone free rate in the two groups revealed better results in favorable anatomy, 76.7%, 87.5%, 100% and 56.2% in stone sizes 0.5–1.0 cm, 1–1.5 cm, 1.6–2 cm, and 2.1–2.5 cm, respectively, vs. 41.1%, 55.5%, 66.6% and 50% in same size stones in the unfavorable anatomy group, as shown in Table 3. However, statistically significant difference (p = 0.04) was found in only stone size of 0.5–1.0 cm category.

The overall stone free rate in lower calyceal stones by ESWL was 71.6% in the present study. When assessed separately by favorable and unfavorable anatomy criteria and residual stones less than 3 mm size were subjected to inversion therapy and mechanical percussion, 86.9% renal units achieved complete stone clearance in favorable anatomy group with one or two favorable factors and 55.5% in unfavorable anatomy group in three months time. In a subgroup of 39 (16.3%) patients, who had all the 3 favorable anatomy factors (IL, IW and IP angle) positive, stone free rate was seen excellent (95.4%) with 2.1 average treatment sessions. A comparison of some of the patient, stone and the imaging data among the present study and the published studies is shown in Table 4.

Discussion

Due to its non-invasive nature, low morbidity and patients' preference, ESWL has become a primary treatment modality for almost 80% of urinary tract calculi [3,4]. Its efficacy as a primary treatment of lower pole calculi has been questioned [5–15]. We herein review our experience of the efficacy of ESWL in a large number of patients with solitary, lower pole renal stones.

The median age of patients in this series was young. It ranged from 20 to 70 years, with the peak age group found in second to fourth decade constituting 175 [73.4%] patients. This was comparable to the results of one local study which reported age range between 15 and 69 years with a median of 35.5 years [11].

Male to female ratio was 2.1:1. A higher male preponderance i.e. 4.5:1 was reported by Rizvi et al. from this hospital way back in 1975 [2]. The marked change in male to female ratio in this study reflects increasing awareness of female patients for treatment. In addition, less invasive nature of treatment attracts them to seek treatment [11].

The size of stones in this series ranged from 0.5 to 2.5 cm. Majority of cases, 99 (40.7%) had stone size of 0.5–1.0 cm, 67 (27.5%) patients had 1.1 to 1.5 cm size stones. A significant number of patients (31.6%) had large size stones, measuring 1.6–2.5 cm in the present series. Tan et al. in their series reported mean stone size of 1.28 ± 0.58 cm with a range of 0.5 to 3.5 cm [12]. Another study mentioned three stone size groups in their data; <10 mm, 10–15 mm and 16–20 mm [13]. Ghoneim et al. reported outcome of ESWL in up to 2.5 cm size stones in lower pole, as in our study [14].

The average number of treatment sessions was 2.1 in this series. Fifty-nine percent of patients required one to two sessions while the remaining 41% >2 sessions. Sahinkanat et al. in their series reported one to two sessions in 72.9% patients, remaining 27.1% required >2 sessions with mean of 1.93 sessions [15]. Stone sizes were smaller

Table 3 Effect of stone size and calyceal anatomy on stone free rate in the two groups (n = 243 renal units).

Size of stones	Favorable anatomy group		Unfavorable anatomy group		*P* value
	n = 128 (%)	Stone free rate (%)	n = 115 (%)	Stone free rate (%)	
0.5–1.0 cm	54 (47.5%)	76.7	45 (39.4%)	41.1	0.04
1.1–1.5 cm	29 (22.4%)	87.5	38 (32.9)	55.5	0.10
1.6–2.0 cm	16 (13.6%)	100.0	15 (12.1%)	66.6	0.10
2.1–2.5 cm	29 (22.4%)	56.2	17 (14.6%)	50.0	0.80

(mean 1.17 cm) in above series justifying more treatment sessions in our patients.

The overall stone free rate in present series was 71.6%. If assessed separately according to favorable and unfavorable anatomy criteria, 86.9% of renal units achieved stone free status in favorable anatomy and 55.5% in unfavorable anatomy group. Raman et al. reported 65% overall stone free rate in their study which was almost similar to our results [8]. Talas et al. reported overall stone free rate of 61.1% [13]. Madbouly et al. reported 73.1% overall stone free rate in their series [16].

Data regarding relationship between stone free rate and calyceal anatomy revealed that the stone free rate was significantly higher in patients with shorter IL (79.8% vs. 42.8%, $p = 0.01$). Stone free rate in patients with wide infundibulum was 83.3% while it was 46.7% in patients with narrow infundibulum ($p = 0.0001$). No significant effect of lower pole IP angle on stone free rate was noted in our series. This is in contrast with a number of previous studies which showed that IP angle plays an important role in eventual stone clearance and it should be taken into account before choosing a modality of treatment [13,17]. In particular, a study by Talas et al. showed that only the IP angle attained significance in predicting a stone free status; IW was seen as another possible predictive factor in their study but this did not reach statistical significance [13]. However, IL was not found to have an important effect in Talas et al. study [13]. This study concluded that an obtuse angle of >70° and a wider infundibulum (>4 mm) had positive effect on outcome [13]. Madbouly et al. noted no significant effect of lower pole anatomy on stone free rate in 3 months when mean IL was 20.9 mm, IW, 5.6 mm and mean lower pole IP angle, 48.33° [16]. We noted a significant effect of IL and IW on stone free rate. Therefore, two of three parameters of prediction were valuable and may be used for prediction in stone clearance. The variable results of IP angle by different workers reflected the different techniques of measurement and differences in normal values [17–29]. The study by Sumino et al. endorses our data in which they concluded that even 1 or 2 favorable factors improved the stone free rate. They reported greater than 60% stone free rate in the group with one or two favorable factors [18]. Most of the studies are in agreement with our results regarding the significance of IW and IL [19,27,28].

A small number of patients who had all 3 favorable parameters of IL, IW and wide IP angle achieved excellent stone free rate in this series (95.4%). Rugerra et al. in their series mentioned 100% stone free rate in all favorable anatomy group and 33% in unfavorable anatomy group [19]. Sumino et al. reported 84.6% stone free rate in all favorable anatomy group [18].

The stone size has definite effect on stone free rate in patients treated with ESWL; in general, the larger the size, the poor is the outcome. However, our study showed that the stone free rates increased with increasing size and favorable anatomy factors. The effect of better stone clearance was seen upto 2 cm stone size. For stones >2 cm, the stone free rate declined again. The exact reason for this phenomenon is not known, but may be related to poor clearance of smaller fragments resulting from disintegration of smaller stones. Sabnis et al. [20] in their study and Poulakis et al. [21] in their series noted 69.2% and 71% stone free rate respectively in 6 months. They reported overall stone free rate without considering the anatomy. If we compare the above results to the present series, stone free rate in favorable anatomy group in the present series is superior. Our

Table 4 A comparison of some study parameters among the present and some previous studies.

Parameters	Present study	Lin et al. [4]	Akhter et al. [11]	Tan et al. [12]	Talas et al. [13]	Ghoneim et al. [14]	Madbouly et al. [16]	Ruggerra et al. [19]	Sabnis et al. [20]
No. of patients	239	112	100	128	198	205	108	107	133
M:F	162:77	84:28	76:24	80:48	130:68	177:28	87:21	68:39	–
Max. stone size (cm)	2.5	2	2	3.5		2.5		2	3.2
Follow-up period (months)	3	3	3	3	3	3	3	3	6
Stone clearance (%)	71.6	43.7	90	62.5	61.1	68.7	73.1	58	69.2
Modality of follow-up	X-Ray+US	X-Ray+US	X-Ray+US	X-Ray+US	X-Ray+US	X-Ray+US	CT scan+US	X-Ray+US	X-Ray+US

series noted reasonably good results with even up to 2.5 cm size stones in favorable anatomy group but statistical significance was only achieved in stones of 1 cm size in the favorable anatomy group. Gerber reported that 65% and 21% of urologists chose ESWL to treat lower pole stones of 1–2 cm and >2 cm in size, respectively, despite published stone-free rate of less than 25% for stones >1 cm size [22].

There are some limitations in the study. Among the stone parameters, we only analyzed the stone size and not the composition or stone density. We used plain X-ray as the modality for determining stone free status rather than computerized tomography (CT) scan, which is more sensitive.

Conclusions

In conclusion, the results from this study show that lower infundibular length and width are significant anatomical factors in determining stone clearance following ESWL treatment of lower calyceal stones and these should be assessed before planning the treatment for lower calyceal stones.

Conflict of interest

The authors declare there are no conflicts of interest.

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